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TECHNOLOGY TRANSITION: *A MORE COMPLETE PICTURE*

Col John B. Wissler, USAF

This article explores the current view of technology transition, why that view can be considered too narrowly focused, and how we can look at it in a broader, more holistic way. Technology transition is the process of inserting technology into military systems so the military can perform its missions. Most of the time, the focus is on incorporating technology into a system, preferably through an interaction between the science and technology (S&T) and acquisition communities. However, there are other ways to view technology transition, such as improving our understanding of the trade space in which the systems designer must operate. This article offers four possible paths for technology transition and gives examples from the Air Force Research Lab's Space Vehicles Directorate.

The Department of Defense currently spends about $10 billion per year on its science and technology (S&T) program, with much of this funding being executed by the services ($5 billion) and the Defense Advanced Research Projects Agency ($3 billion) (Office of the Undersecretary of Defense [Comptroller], 2005). Over the years, this vast S&T program has been instrumental in the military's ability to field advanced weapon systems that help the United States achieve dominance on the battlefield.

By itself, S&T does not produce weapon systems; the systems must be designed, developed, tested, manufactured, fielded, and supported by the acquisition, contractor, test, and sustainment communities to ensure the operational community has the tools it needs to be ready for war. This happens according to a process captured in documents such as the DoD 5000-series regulations. The Department of Defense (DoD) judges the success of its overall research, development, test, and evaluation (RDT&E) program, including S&T (i.e., the "R" of RDT&E) investment, by how efficiently and effectively the program produces the systems it needs for maximum military capability at lowest

possible cost. To zero in on the S&T investment, DoD tends to declare it a "good" investment if the technology actually ends up in a weapon system. The means by which a technology becomes part of a weapon system is termed "technology transition," or T2. Although there are several more or less official definitions that are summarized below, there are actually a variety of ways technology transition can happen. Given the amount of annual S&T spending, it is worth exploring the current view of T2, why that view is too narrowly focused, and how we can look at it in a broader fashion.

THE CURRENT VIEW

The 5000-series instructions govern the way DoD develops and acquires new weapon systems. They stipulate that the S&T program will address user needs, maintain a broad-based science program to anticipate future needs, and enable rapid, successful transition of technology to useful products (para. E1.28). They also say that "advanced technologies shall be integrated into producible systems and deployed in the shortest time practicable." Although rapid transition is the goal, it is a goal that is not always met. For example, the DoD Inspector General recently criticized the services for not following "best practices" and ensuring the technology is rapidly transitioned to military systems (DoD IG, 2004).

What is T2? The Defense Acquisition University (DAU) defines it as "the process of inserting critical technology into military systems to provide an effective weapons and support system in the quantity and quality needed by the warfighter to carry out assigned missions." Randy Zittel of DAU defines it simply as "the insertion of new technology into military systems…for the 'best value' as measured by the military operator" (2003). Thus, there is a definite link between the technology we develop and the acquisition system that fields the weapons systems the operational community uses,

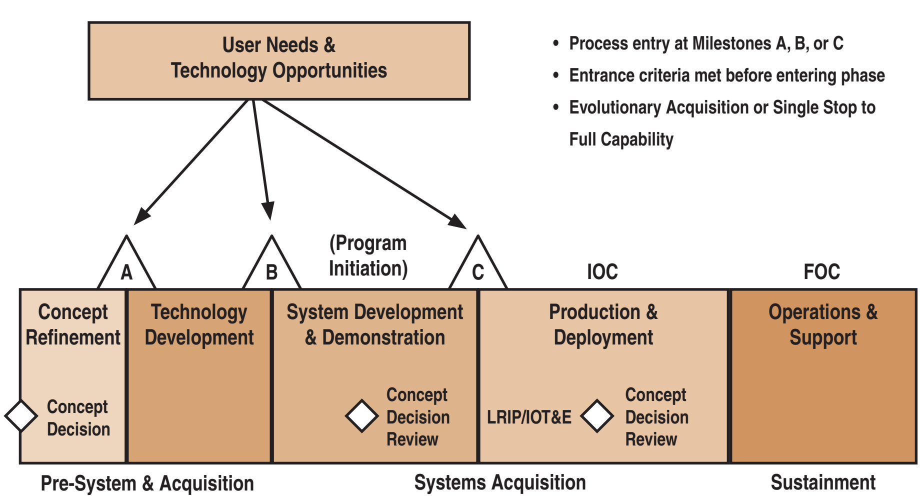

FIGURE 1. TRANSITION DURING ACQUISITION PROCESS

and this transition can occur at any time during the acquisition process, i.e., Milestones A, B, or C, as shown in Figure 1. Depending on the program's phase, the transition can occur between government organizations for use in a specific system, can be from government to industry, or can be from industry to government (Defense Procurement and Acquisition Policy [DPAP], 2003).

Now that we know what T2 is, the next question is how does it happen? The DAU Program Manager's toolkit offers a comprehensive list of mechanisms that are used to move technology from the S&T realm to the operational realm, generally via established acquisition programs. These mechanisms include Advanced Technology Demonstrations (ATDs), Advanced Concept Technology Demonstrations (ACTDs), Joint Experiments (JEs), and Warfighter Rapid Acquisition Programs (WRAPs).

For example, ATDs are S&T programs that the defense S&T community operates. They are targeted at a funded acquisition program for technology insertion within 5 years. The ATDs are supposed to be funded in Budget Activity (BA) 3 (Advanced Technology Development) and have agreed upon exit criteria and a transition plan (DPAP, 2003).

The ACTDs are programs that take relatively mature technologies (i.e., "post" ATD) and assess and integrate those technologies. They are usually funded by BA 3 and have the goal of producing a prototype for the operator, who is heavily involved in the demonstration. Like ATDs, they have agreed-upon criteria and transition plans, to include provisions for residual operational capabilities when appropriate, but unlike ATDs, they are largely under the control of the operator (DPAP, 2003).

The JEs are operational experiments in a joint arena in which scientific methodologies are used to assess joint warfighting concepts and doctrine. As such, they require mature technologies and may use ATD or ACTD products (DPAP, 2003). The JE's goal is not to develop new technologies, but to capitalize on them by defining new operational concepts.

Finally, the WRAP is intended to address the funding gap that typically happens between the end of technology development and the beginning of a formal acquisition program (i.e., Milestones B or C), before funds can be allocated for the program (DPAP, 2003). The original WRAP was started by the Army, which no longer funds it, but the concept has been adopted by DoD and operates at a relatively small level.

Within the general idea of T2 and the mechanisms used to facilitate it, different communities have different roles. For example, the S&T community is charged with addressing all sciences not being investigated by industry and overseeing technology development until it is mature enough to be inserted into new systems. The acquisition community oversees the maturation of that technology until it is "fully incorporated" into a "specific weapon system" (DPAP, 2003).

DEFICIENCIES IN THE CURRENT VIEW

If we consider this brief summary of T2, one theme jumps out: the overwhelming focus on incorporating or inserting technology into a system, preferably through an interaction between the S&T and acquisition communities. The current acquisition

policy guidance and practices emphasize T2 as the primary means of expediting "transition from laboratory to operational use" (DAU, 2003). The ATD, ACTD, JE, and WRAP transition mechanisms mentioned above usually demonstrate systems or, possibly in the case of the JE, system-of-systems, with the implication being that a technology is inserted as a component (e.g., a focal plane array or a turbine blade) or a subsystem (e.g., the radar module in a sensor system). Thus, "insertion" occurs when that technology is a recognizable part of the final operational system. This systems emphasis means that technologies that are not recognizable parts of the final operational system are frequently considered not to have not transitioned. Frequently, the resulting conclusion drawn is that those technologies have not generated any return for the funds invested in them.

The focus on insertion of technology into systems can also lead us to an orientation on products as tangible things we can touch or see (i.e., the focal plane array or the turbine blade). Such a mindset ignores the fact that a goal of S&T is not necessarily the products themselves, but the ability to build those products. Thus, S&T is frequently more about the knowledge we need to make a product than about the product itself. Knowledge can express itself in a variety of ways. In addition to being about how to do something, it can also be about how not to do something. It can also have unexpected payoffs; knowledge that we think is applicable in one area may turn out to have applications in a completely different area or areas.

In today's acquisition world, it is generally not the government program office that identifies technologies and selects them for insertion into new weapon systems.

Thinking in terms of systems design, one aspect of S&T that can be extremely important, but which tends to be ignored in a product-focused mindset, is that it can help develop a better understanding of the trade space in which systems designers must operate as they attempt to satisfy requirements and meet cost and performance goals. Examples include trade-offs between strength and weight for aircraft structural materials or protection and weight for satellite radiation shielding. Such trade-offs introduce a series of risk-inducing or mitigating choices that must be made. The knowledge we have from S&T allows us to reduce the overall risk as we work within that trade space, even if there are no actual technologies that we "insert" into the final design. The focus on transition into an operational system ignores this benefit.

In today's acquisition world, it is generally not the government program office that identifies technologies and selects them for insertion into new weapon systems. What happens more often is that the program offices rely on the contractors to identify and insert the technologies, based on the belief that the contractor will always use the best

source (DPAP, 2003). This means the government no longer specifies the solutions or necessary technologies needed for systems development. The contractor makes the decision based on requirements, risk, and funding available. Because the contractor's goal is to meet the government's need at the lowest possible cost and risk in the time specified, this decision may not be in favor of using the most advanced technology. Frequently in fact, due to funding shortfalls, "great ideas in the laboratory many times do not translate easily into workable [DoD] systems" because funds are needed to mature and test ideas (DPAP, 2003). Tying T2 success strictly to whether or not technology is actually inserted into a system entails using a metric over which the government has little control. Even so, technologies in DoD are frequently transitioned at much lower maturity levels (e.g., technology readiness levels [TRLs] of 4 to 6) than in the commercial world (e.g., TRLs of 8 to 9) (GAO, 1999).

So we have a situation, at least from an S&T perspective, wherein the primary means of judging the success of the government's S&T investment is narrowly focused on a view of technology as it actually appears in a new system as developed in the DoD acquisition system (i.e., via program offices). This viewpoint ignores other possible benefits of that investment, and therefore ignores other ways in which that investment can contribute to new military capability. The S&T is fundamentally about knowledge, not products. Specifically, it is about how to do something (as perhaps embodied in an ATD), how to use something (as in an ACTD or JE), how to increase our ability to create something (e.g., developing improved design codes), or even how not to do something (e.g., an applied research project that proves to be impractical).

In other words, we may be selling ourselves short by making budget and investment decisions based on what could be considered the erroneous view that there is no return on the S&T investment. This sets up a scenario that we could under invest over the long term, thereby placing at risk not only future capability, but also our ability to respond to short-term, unanticipated needs. Additionally, by focusing only on transition through program offices, we may be ignoring other opportunities in which a technology may have applications. A broader view may be in order.

AN ALTERNATE VIEW

Because we need to think about technology transition in terms of knowledge and specific systems or components of systems, our model for T2 must be broader than the model generally considered within DoD. In the Air Force Research Laboratory's (AFRL) Space Vehicles Directorate, T2 is viewed as having four possible paths, any one of which represents a valid means of transitioning technology to the operational user (Figure 2).

The first path, transitioning technology directly through a contractor, can happen in one of two ways. In some cases, it is possible to work for a prime contractor developing a system for a program office, and thus function essentially as a sub-contractor to that prime contractor. This case is exemplified in Figure 2 by the Defense Meteorological Satellite Program (DMSP), in which AFRL uses its space environment expertise to design, build, test, and provide space environment sensors to Northrop-Grumman, the

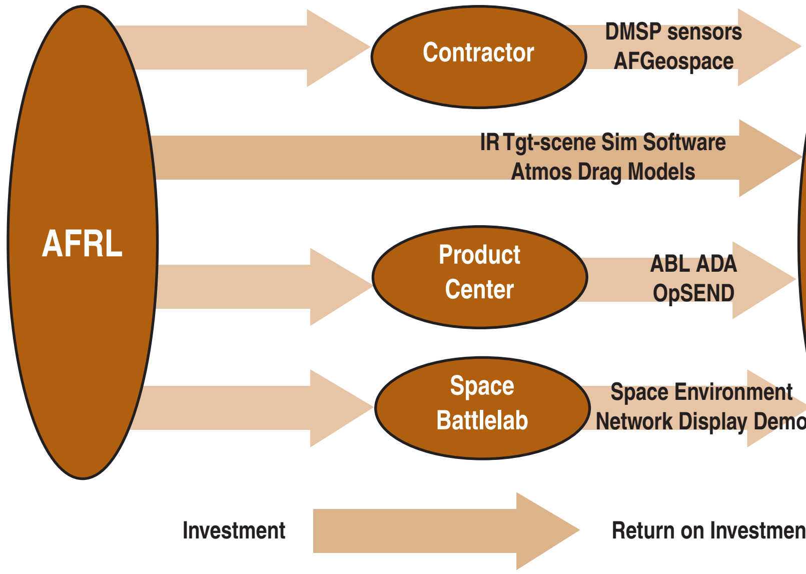

FIGURE 2. FOUR POSSIBLE T2 PATHS IN THE AIR FORCE RESEARCH LABORATORY'S (AFRL) SPACE VEHICLES DIRECTORATE

satellite builder, who is under contract from the Space and Missile Systems Center. A second example is a physics-based software program called AFGeospace, which AFRL developed and continues to upgrade and provide to the space community (with over 400 users to date). This program allows satellite system designers to accurately compute the space environment that their satellite will experience, thereby allowing them to manage cost, performance, and risk (e.g., through trade-offs in shielding versus weight).

In the first case, the relationship with the contractor may not be captured in the standard acquisition approach because it is not directly through a program office. In the second case, there is no system or technology that is actually transferred. Therefore, in the traditional DoD view, T2 has not occurred. Clearly, however, it has taken place in the AFGeospace example, because AFGeospace is an enabler for robust satellite design even if one cannot point to a piece of a satellite and identify a technology that was transferred. An analogous example from the aeronautical community might be a computational fluid dynamics code that allows a designer at an aircraft manufacturer to compute flows over a proposed aircraft design.

The second path involves transitioning technology straight to the user, generally in response to a short-term, urgent requirement. This may sound like the WRAP approach, but it is different in that there may not be an acquisition program waiting to receive the technology. The Infrared Target-scene Simulation Software (IRTSS), operatingon commercially available desktop and laptop computers, allows combat aircrews to integrate commercially available overhead satellite imagery, target characteristics, mission parameters, and weather predictions to produce a "sensor's eye" view of the target area, thereby enhancing their situational awareness over the target area.

Although it had been under development for some time, AFRL fielded it directly to fighter units before Operation Iraqi Freedom in response to high priority requests. It continues to be used today and will eventually be formally transitioned (in the traditional sense) to the Air Force Materiel Command's Electronic Systems Center. Atmospheric drag models, developed originally by the Air Force Geophysics Laboratory, continue to be refined by AFRL today. In this case, AFRL provides them directly to Air Force Space Command (AFSPC), where they are used in predicting space object orbital paths, a necessary element of space situational awareness since AFSPC cannot track all space objects continuously. In both of these cases, because of the user's need and because of the laboratory's expertise, direct transfer to the user is the path that makes the most sense.

The third T2 path is the traditional one, via a product center program office. In Figure 2, the two examples are the Airborne Laser Atmospheric Decision Aid (ABL ADA) and the Operational Space Environment Network Display (OpSEND). The ABL ADA was developed by the AFRL for the ABL program office as part of the Missile Defense Agency's ABL theater missile defense program. Because a laser weapon system is sensitive to atmospheric temperature fluctuations and clouds, and because these two parameters can vary greatly in response to the weather, the laboratory developed the ADA to incorporate standard weather predictions, regional characteristics, atmospheric transmission models, and laser characteristics to predict laser performance for test or operational missions.

In the second example, the laboratory developed OpSEND in order to provide military users current awareness of the space environment and its effects on space systems, particularly communications and navigation links. It was transitioned to the SMSC)and is maintained by the Air Force Weather Agency, which hosts it on a computer network and makes it available to anyone in DoD with the right kind of access. Among other purposes, it has been used to diagnose communication and navigation anomalies for U.S. Central Command. In both of the above examples, the laboratory matured the technology to the point where a program office accepted it either as ready for operations or as part of an ongoing acquisition program.

The last transition path is via the Space Battlelab, an Air Force Space Command organization that develops "innovative and revolutionary applications of space systems" (Air Force Space Battlelab, 2005). The example in Figure 2 is the Space Environment Network Display (SEND) demonstration, an earlier, less mature version of OpSEND that was provided to the Battlelab for evaluation as to its utility in space operations. In this case, the demonstration was successful enough that the Battlelab recommended its further development, resulting in the OpSEND product discussed above. This last transition path is very much like the ACTD or JE, because the operational user is closely involved in the demonstration.

In all of the above examples, each transition on the right side of Figure 2 represents a return on the investment that the Air Force made through AFRL on the left side of Figure 2. All of the transition targets, whether they are the user, industry, program offices, or the Space Battlelab, are valid recipients of that technology. The technology itself flows down a particular pathway to the target in the way that makes the most sense for it and the target in order to achieve best value for the DoD.

Another way of looking at T2 is to consider the systems engineering process, shown in Figure 3, and to think about the role it can play. On one hand, T2 could occur as part of the systems engineering process when the technology base provides component-level technologies that are or will be mature enough to eventually be incorporated into the system under development. In a more holistic sense, however, another form of T2 can occur when the technology base provides a foundation from which the designers can engage in the "art of the possible" as they work their way through the needs the system must meet and the requirements it must satisfy; an analysis of the functions the system must perform in order to meet those requirements and how to allocate requirements to those functions; and the development of candidate system and component solutions to meet those requirements (Space and Missile Systems Center, 2003). As the process unfolds, trades must be made between competing factors that will affect the program's overall cost, schedule, and performance. Some solutions will be more acceptable than others and some solutions will be unacceptable because they are unworkable, violate physics, are too expensive, or will take too long to implement.

The S&T investment is a key process enabler that allows the designers to do their work; this implies that there has been a transfer of knowledge and capability. In that sense, T2 has occurred, even if there are no identifiable products on the final system that are directly traceable back to an S&T investment. The AFGeospace example in Figure 2 demonstrates how T2 can occur in this framework. With it, a satellite system designer can look at different orbits and the radiation environment in which that system will operate, then use that information to balance between shielding, lifetime, and other parameters. While AFGeospace is not part of the finished system, it is a technology that leads to the finished system because it enables intelligent, informed design choices and decisions to be made. Similarly, S&T in materials, propulsion, electronics, and other

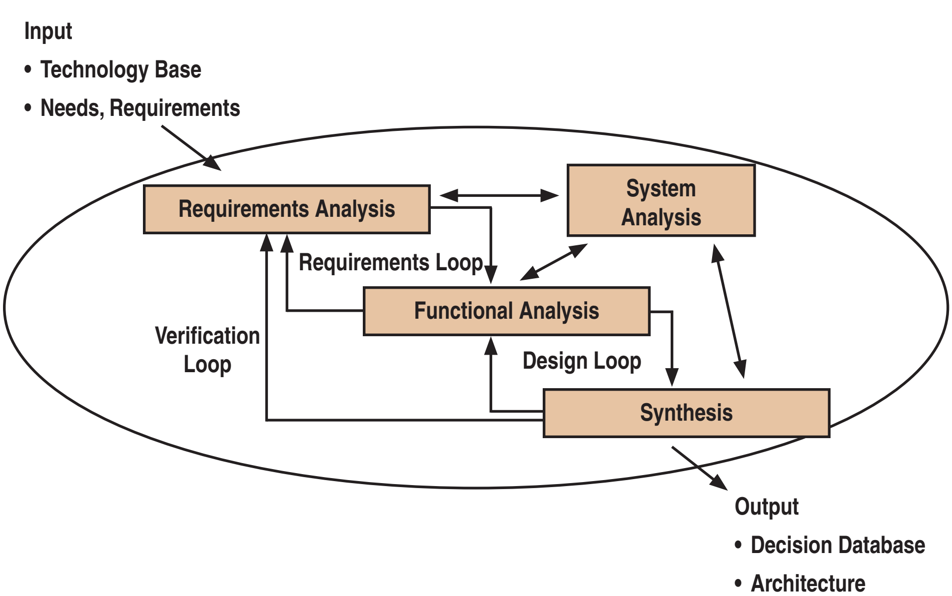

FIGURE 3. THE SYSTEMS ENGINEERING PROCESS

areas can be transitioned and serve a useful purpose even if a particular material, a specific turbine blade design, or a new chip design does not become part of a finished product.

A WAY AHEAD

If we accept that T2 can have a broader meaning than its traditional definition, we can take some steps to make that understanding a reality.

One approach is to account for this broader meaning during annual S&T reviews. Because the reviews are generally a joint affair between the acquisition and the S&T communities, they tend to focus on the standard laboratory/System Program Office (SPO) transition mechanism. The acquisition community needs to recognize that there are other ways for T2 to occur, and consider those pathways as legitimate methods to put technology into the hands of the users. The S&T community needs to accurately track these alternate paths, and present them in a coherent manner during the reviews,. Examples include an accounting of contractors who have used knowledge gained via DoD S&T investment, users who have received S&T products directly, and JEs that have investigated particular technologies. Going back to DoDD 5000.1, the reviews should remember that the S&T program is to "enable rapid successful transition from the S&T base to useful military products," which can be considerably more than actually incorporating a specific component-level technology into a military product.

If we accept that T2 can have a broader meaning than its traditional definition, we can take some steps to make that understanding a reality.

Another approach is to develop metrics that allow us to calculate Return on Investment. The first metric could be the number of users of a particular technology, such as a software program or algorithm, engineering data, a hardware item, or even expertise needed to solve a particular problem. Returning to the AFGeospace example, there are over 400 users today, which would indicate quite a large return on investment, particularly if one considers the value of the work those 400 users accomplish. Another metric is to divide the total Demonstration/Validation (BA 4) funds in a program by the Advanced Technology Development funds that were used to produce a technology that allowed the program to move forward, particularly if that technology is on a critical path. Returning to the DMSP example, the sensors AFRL developed are critical to the overall mission of the satellite, which is worth billions over the program's life, and AFRL spent a few tens of millions of dollars developing those sensors. This approach

is somewhat dangerous, because it could be manipulated, but that is true of any metric. The real point is to show that the return is nonzero.

However, not all advanced technology development projects transition successfully, either because they fail or because there is not enough funding to pay for the transition. In the first case, it is incumbent on the S&T community to end the work and move on to other, perhaps more successful, technologies. We should always remember that even failures have value and if the knowledge of that failure is used at a later date, then the work had some value. In the second case, the need for the technology presumably still exists. Therefore, perhaps the only viable option is to prepare data packages and submit them to the Defense Technical Information Center (DTIC), where the knowledge is preserved for later use, perhaps to be inserted into a system via a spiral acquisition.

One means of linking technology developments with programs is via the Technology Transition Plan or Agreement (TTP or TTA).

One means of linking technology developments with programs is via the Technology Transition Plan or Agreement (TTP or TTA). The basic agreement is composed of the following items: capability description, target acquisition program, acquisition program technical need, integration strategy, and who the players are in the acquisition and S&T communities. Additionally, there are details on the status and risk of the technology being transitioned, how it is being developed, how its readiness will be measured, and the program plan of the target program (Zittel, 2005). These plans are currently aimed at the traditional acquisition model (i.e., through an acquisition program office), but they should also be expanded to include all the paths outlined in Figure 2. We should remember, however, that industry actually develops the systems, and as such selects technologies for transition into those systems based on overall program goals and risk and the technology's TRL. Therefore, it may be that the concept of a plan or agreement between two government entities, the program office and the laboratory, in isolation from the contractor developing the system, is no longer appropriate today.

CONCLUSION

This article has examined T2 and put forth the argument that the focus on it as the insertion of a technology into a system is perhaps too narrow. It leads us to undervalue the real impact of DoD's S&T investment and to possibly ignore other ways technology can benefit its ultimate customer, the operational user. There are four ways T2 is used

at the AFRL: direct to industry, direct to the user, through a program office, or through a battlelab or other operational experimenter. All of these mechanisms are valid and all should be counted and used in order to achieve best value for DoD. Additionally, it is not necessary for a technology to actually appear as a physical part of a system; it can be transitioned successfully if it is used as part of the systems engineering or design process. At its core, technology transition is fundamentally about transfer of knowledge and understanding; how we accomplish T2 should be structured to take full advantage of those characteristics.

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